Validation of the OMI $O_2 - O_2$ cloud product with MODIS in the "A" train

Maarten Sneep[*]*, Pepijn Veefkind, Johan de Haan and Piet Stammes*

Cloud correction is an important step in the retrieval of trace gases. For OMI this correction can be based on cloud properties provided by the OMI $O_2 - O_2$ cloud product. Validation results of the OMI $O_2 - O_2$ cloud product using MODIS/Aqua Collection 005 data are presented here.

1. The "A" train

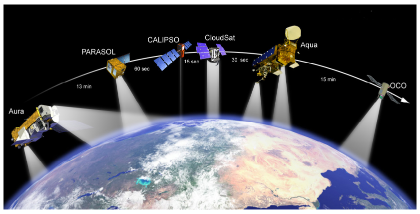

Figure A. The satellites in the "A" train.

2. Co-locating OMI and MODIS

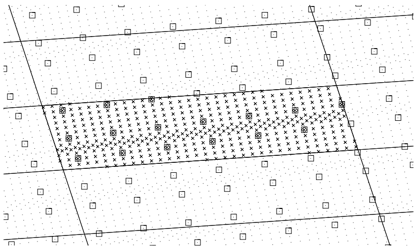

Figure B. Co-location of OMI and MODIS measurements. The dots indicate the centres of the $1 \times 1\,\mathrm{km}^2$ MODIS cloud optical thickness pixels, the squares the centres of the $5 \times 5\,\mathrm{km}^2$ MODIS cloud pressure pixels. The lines show the boundaries of the OMI pixels.

3. The effective cloud fraction

The cloud fraction as retrieved by the OMI $O_2 - O_2$ algorithm is an *effective* cloud fraction c_{eff}, which is a direct measure for the effect of clouds on short wave radiation. The MODIS cloud fraction, however, is measured in the infra-red, and represents a *geometric* cloud fraction. We therefore use the MODIS cloud optical thickness τ_c (at 650 nm) to obtain the cloud reflectance, using a radiative transfer model, and from that the effective cloud fraction. All clouds are treated as water clouds in this conversion:

$$c_{\mathrm{eff}} = R(\tau_c; \theta_0, \theta, \phi - \phi_0)/0.8$$

The factor 0.8 is the albedo of the Lambertian surface used to represent clouds in the OMI $O_2 - O_2$ cloud retrieval model. Experience with the FRESCO O_2 A-band cloud algorithm for GOME has shown that this gives appropriate values for cloud correction in trace gas retrievals.

4. The cloud pressure

The OMI $O_2 - O_2$ cloud retrieval algorithm uses the depth of the collision induced absorption by oxygen at 477 nm to retrieve the cloud pressure. This is the strongest O_2 absorption band in the OMI wavelength range. MODIS and meteorological satellites on the other hand use thermal infra-red radiances to determine the cloud top height. These are much more sensitive to thin ice clouds, and in general retrieve a much lower cloud pressure than visible spectroscopic measurements; for GOME an average difference of 50 hPa to 100 hPa between infra-red and visible retrievals is found.

Table 1. Differences in c_{eff} and p_c (OMI – MODIS)

c_{eff} difference	0.01	p_c difference, $c_{\mathrm{eff}} > 0.05$	86 hPa
Spread (1σ)	0.12	Spread (1σ)	219 hPa
Correlation coefficient	92 %	Correlation coefficient	56 %
p_c difference, $c_{\mathrm{eff}} > 0.2$	165 hPa	p_c difference, $c_{\mathrm{eff}} > 0.5$	237 hPa
Spread (1σ)	171 hPa	Spread (1σ)	142 hPa
Correlation coefficient	71 %	Correlation coefficient	76 %

5. Distribution of differences

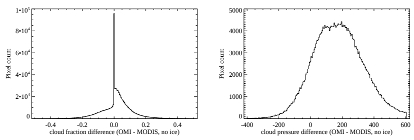

Figure C. Histogram of the differences in the effective cloud fraction and the cloud pressure. Pixels with an OMI $c_{\mathrm{eff}} < 0.05$ were removed from the cloud pressure comparison.

6. Scatter density plots

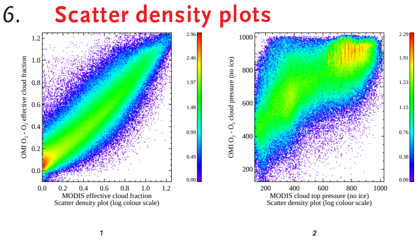

Figure D. Scatter density plots of the OMI and the MODIS measurements. 1: the effective cloud fraction. Cloud-free pixels were removed from this plot. 2: the cloud pressure. Pixels with an OMI $c_{\mathrm{eff}} < 0.25$ were removed from the comparison. Both plots use a logarithmic colour scale.

There is no clear dependence of the difference in the cloud pressure on the latitude, see figure E.1.

For low cloud fractions the MODIS data seems to be contaminated by ground surface radiation, while for high cloud fractions the cloud pressure retrieved by MODIS is lower than the OMI $O_2 - O_2$ cloud pressure, as expected. This is illustrated in figure E.2.

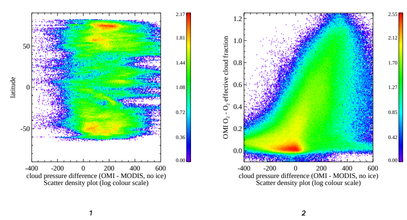

Figure E. 1: The difference in the cloud pressure as a function of the latitude. 2: The difference in the cloud pressure as a function of the OMI effective cloud fraction. Both plots use a logarithmic colour scale.

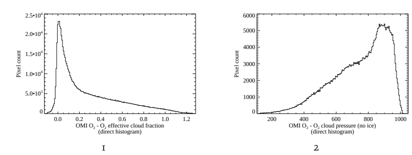

Figure F. 1: Histogram of the effective cloud fractions. 2: Histogram of the cloud pressures.

7. Geographical distribution of differences

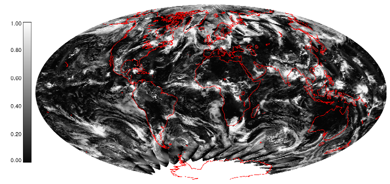

Figure G. The OMI effective cloud fraction.

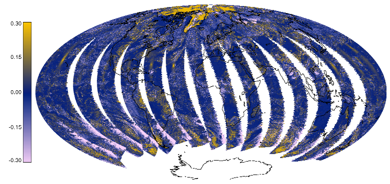

Figure H. Plot of the differences in the cloud fraction (OMI – MODIS).

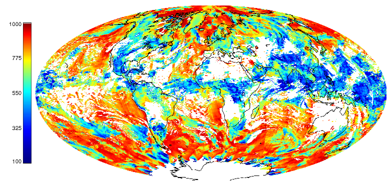

Figure I. The OMI cloud pressure in hPa, for pixels with $c_{\mathrm{eff}} > 0.05$.

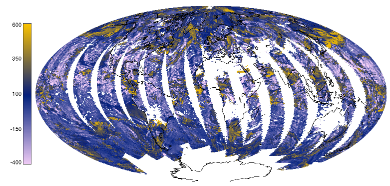

Figure J. Plot of the differences in the cloud pressure in hPa (OMI – MODIS), for pixels with $c_{\mathrm{eff}} > 0.05$.

8. Conclusion

The availability of MODIS on the "A" train provides a useful data-source for the validation of the OMI $O_2 - O_2$ cloud fraction. The cloud effective fraction agrees well with our expectations: it is a radiative measure of the clouds in the scene.

The $O_2 - O_2$ cloud pressure is harder to validate using MODIS data, because of the different retrieval wavelength regimes. This difference makes the MODIS cloud pressure much more sensitive to thin ice clouds than OMI measurements. Validation of the cloud pressure will have to be extended with ground measurements and Cloudsat/Calipso instruments.

Koninklijk Nederlands Meteorologisch Instituut

Royal Netherlands Meteorological Institute, PO Box 201, 3730 AE De Bilt, The Netherlands.

[*]*email: maarten.sneep@knmi.nl*

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